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CONTENTS

Research Notes

COVER: Ancient mexican bird motiff from a flat stamp found near Guerrero, Mexico.

Reconnaissance Geology of Cedros Island, Baja California, Mexico

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Abstract.—Cedros Island is composed of late Jurassic melange of Franciscan aspect (herein designated Cedros Formation) which nearly everywhere is in tectonic contact with ophiolite and a superjacent sedimentary sequence of middle Jurassic to late Cenozoic age. Analogy with structural relationships in California suggests that the Cedros Formation was subducted beneath the ophiolite as oceanic and continental plates converged. Subduction was initiated during latest Jurassic time and concluded during the early Cretaceous. The San Carlos fault, presumably the subduction surface, may be a southern extension of the Coast Range thrust. During late Cenozoic time, three bodies of Cedros Formation were uplifted along faults which truncated ophiolite, superjacent rocks through Pliocene age, the San Carlos fault, and the San Agustín shear zone.

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Cedros Island, which lies off the Pacific Coast of Baja California (Fig. 1), reveals an extensive Mesozoic and Cenozoic record of the peninsular borderland. Previous, but essentially fragmentary reports of the island geology, have been made by Veatch (1869), Hanna (1925, 1927), Tafall (1948), Hutchins (1950), Mina (1957), van West (1958), Kilmer (1972) and Jones et al., (1976). This paper, based upon reconnaissance mapping (1963–74), presents a graphic summary of the island geology (Figs. 2, 3, and 4) and a brief discussion of Cedros Island ophiolite, late Mesozoic subduction history and Cenozoic structural development. Nine formational units were mapped, five of which are new, including the Cedros, Choyal, Gran Cañon, Coloradito and Morro Redondo formations; formal descriptions will appear in a future paper.

Basement Rocks, Ophiolite and Their Relations

Cedros Formation.—This melange-structured unit, which includes graywacke, shale, chert, volcanics, limestone, serpentinite, amphibolite, and glaucophane schist, is reminiscent of the Franciscan assemblage of California. A new name—Cedros Formation—is provisionally designated because (1) detailed comparative lithologic studies of the two formations have not been made, (2) geographic continuity with undoubted Franciscan of southern California, 600 km northwest, has not been demonstrated, and (3) some lithologic differences exist, though slight, in that limestones are more abundant in the Cedros, and bedded black cherts, rare or non-existent in the Franciscan, are relatively common. Radiolarians from one chert indicate a late Jurassic age (Jones, pers. comm., 1976); those from another chert have a late Jurassic-early Cretaceous range (Riedel, pers. comm., 1974). This fossil evidence coupled with the recognition of Cedros detritus in the superjacent Coloradito Formation of probable latest Jurassic age suggests that the Cedros age is latest Jurassic and (?) older. Other occurrences of Cedros Formation in Baja Cali-

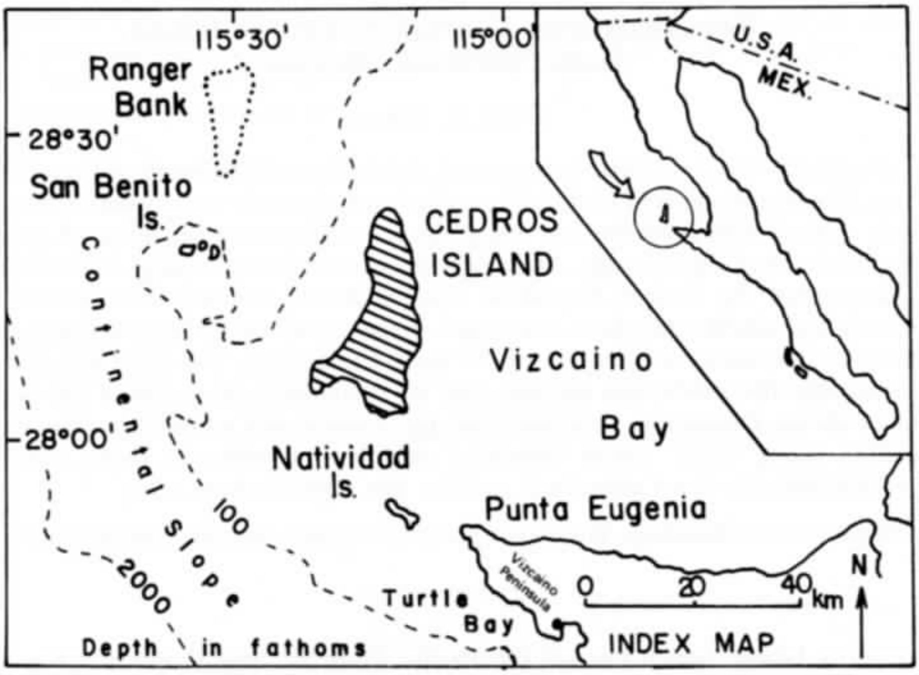

Fig. 1. Index Map.

fornia, apparently include Ranger Bank (Emery, 1948), and the San Benitos Islands, where Cohen et al., (1963) referred it to "Franciscan Group."

Choyal Formation.—This formation consists of three steeply dipping units which, along the north and northwest slopes of Monte Cedros, are in fault contact with the Cedros Formation along the San Carlos fault. The belts, in order of superposition are (1) 150- to 350-m wide belt of sheared peridotite and serpentinite, which is separated from the Cedros Formation by the San Carlos fault, (2) an intermediate, 500-m wide belt of sheared, hornblende gabbro and diorite and (3) a belt of pillow-structured greenstones intruded by trachyandesite dikes. At Punta Norte, the greenstones are also intruded by eight small plutonic bodies composed of granodiorite, quartz diorite, and gabbro. The granitic intrusions apparently are younger than the trachyandesite dikes. Suppe and Armstrong (1972) dated two quartz diorite cobbles from Punta Norte at 142 ± 13 my and 148 ± 6 my, indicating late Jurassic plutonism. The Choyal is interpreted as an oceanic crust/mantle remnant because of its similarity to rock sequences in California which Bailey et al., (1970), concluded were fragments of ancient oceanic crust.

Gran Cañon Formation.—The lower third of this unit is radiolarian siliceous shale which rests depositionally upon Choyal greenstones. The siliceous shales grade upward into a clastic section including hornblende-rich sandstones, siltstones, andesitic conglomerate, and minor volcanics. *Bositra buchi* (Roemer), a small marine bivalve from near the middle of the formation, indicates a middle

CEDROS ISLAND GENERALIZED STRATIGRAPHY

AGE	FORMATION AND MAP SYMBOL	COLUMN	Thickness M	LITHOLOGY
Quaternary	Alluvium, dunes landslides Fanglomerate Marine terrace deposits (4)		5-50	Sand and gravels
Early to Late Pliocene	ALMEJA		100-150	Conglomerate, sandstone, bioclastic (algal-rich) rock, friable sands.
Late middle Miocene	TORTUGA		980	Organic siltstone and claystone; sandstone, conglomerate.
Late Cretaceous: Turonian	MORRO REDONDO	Not in contact	100	Conglomerate, variegated silty shale and sandstone, tuff.
Late Cretaceous: Turonian to Cenomanian	VALLE: Upper	Not in contact	2200-2900	Concretionary sandstone, conglomerate; thin, graded ss/silty shale beds; shale.
Late Cretaceous: Turonian to Cenomanian	VALLE: Lower		900 2,300	Thin, graded ss/silty shale beds; shale, concretionary and lenticular sandstones, conglomerate, tuff(?).
Early Cret. - Late Jurassic	EUGENIA		100-150	Congl., graywacke, shale, andesitic flows or sills. (Andesite dikes)
Late Jurassic	COLORADITO		150-600	Megabreccia, interbedded shale, sandstone, congl. (Andesite dikes)
Middle Jurassic (Bajocian-Callovian)	GRAN CANON		1900-2200	Siliceous shale, silty shale, sandstone. Conglomerate, pillow-structured volcanics, tuff.
Pre Middle Jurassic	CHOYAL "OPHIOLITE"		?	Massive and pillow-structured volcanics, breccia, chert. Intruded by trachyandesite and granitics.
				Hornblende diorite and grabbro. Sheared
				Peridotite, serpentinite Pervasively sheared
		FAULT CONTACT		
Late Jurassic ?	CEDROS		?	Graywacke, shale, chert, pillow-structured volcanics, limestone, glaucophane and actinolite rock; serpentinite

Fig. 2. Generalized Stratigraphy of Cedros Island.

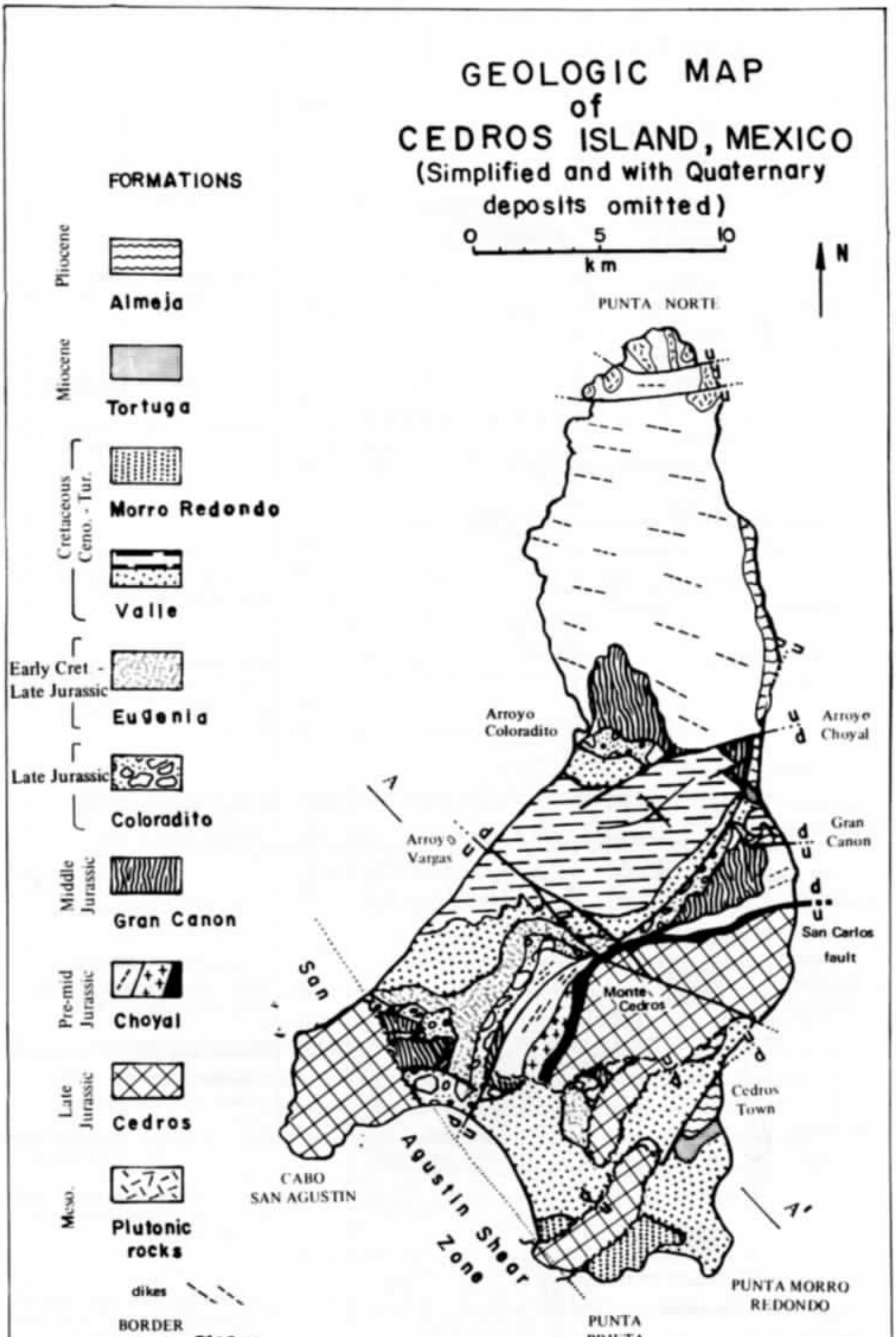

Fig. 3. Generalized Geologic Map of Cedros Island.

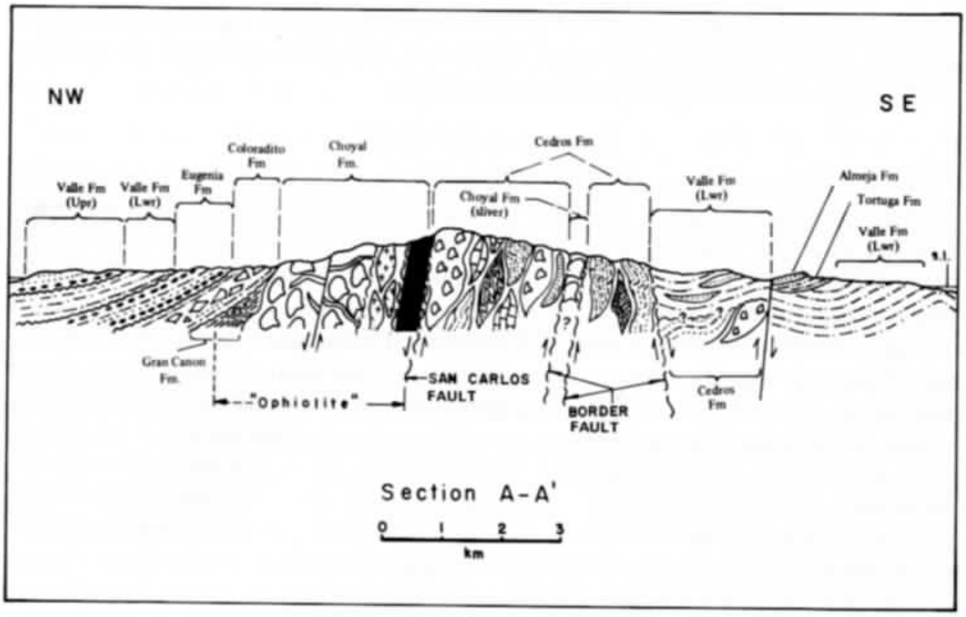

Fig. 4. Geological Section A-A'.

Jurassic (Bajocian-Callovian) age (Imlay, pers. comm., 1968). Similar lithologic sequences, which rest depositionally upon oceanic crust, are reported from the Coast Ranges (Bailey et al., 1970; Page, 1972), but these appear younger (i.e., late Jurassic-early Cretaceous) than the Gran Cañon. Gran Cañon correlatives may occur in the Sierra Nevada or Peninsular Ranges which include middle-late Jurassic sedimentary sequences (Schweikert and Cowan, 1975; Imlay, 1964).

Cedros Island Ophiolite.—If the Choyal is correctly interpreted as an oceanic lithosphere remnant, then siliceous shale of the Gran Cañon and the Choyal constitute an ophiolite. The ophiolite is not completely exposed at any one place because of faulting and overlap by younger beds. The Choyal peridotite/serpentinite and gabbro/diorite belts are exposed 5 km west of Cedros town, while Choyal greenstones and Gran Cañon siliceous shale are revealed in Gran Cañon.

The San Carlos Fault and Subduction

The San Carlos fault is a steeply dipping, northeasterly trending fault which separates Cedros and Choyal formations along the western and northern slopes of Monte Cedros. Along it, Cedros rocks are locally foliated and altered to glaucophane schist, while the adjacent Choyal serpentinite/peridotite belt is pervasively sheared. The arcuate pattern of the Choyal, dipping steeply away from a Cedros "core," suggests that the Cedros Formation structurally underlies the Choyal. The absence of dikes in the Cedros, so widespread in the overlying Choyal, coupled with melange development within the Cedros Formation itself, suggests that the Cedros was tectonically emplaced beneath the Choyal, either by subduction of Cedros or obduction of Choyal. Given substantial evidence favoring Mesozoic subduction in California, (Schweikert and Cowan, 1975; and others),

Cedros emplacement is explained by subduction along the San Carlos fault, beneath a westerly-moving continent which had earlier incorporated an ophiolite (Choyal-Gran Cañon) along its western margin.

Duration of Subduction

Detritus of probable Cedros origin occurs in two formations which lie depositionally immediately above the Gran Cañon, including the Coloradito (late Jurassic) and Eugenia, (latest Jurassic-early Cretaceous). The Coloradito is composed of megabreccia and interbedded units of thinly bedded sandstone and shale. The megabreccia includes blocks of (1) abundant black chert, green chert, graywacke and greenstone of Cedros aspect, (2) occasional limestones, some of which contain Paleozoic fossils (Jones, pers. comm., 1976) and (3) rare Gran Cañon sandstone. These blocks "float" in a dark gray, shaly matrix of probable Cedros origin. In the Eugenia conglomerate, rare glaucophane schist occurs at one place.

To account for Cedros detritus in the Coloradito, it is postulated that subduction began in latest Jurassic time with Cedros rocks being, in part, uplifted along the converging continental/oceanic plate margin so that elevated blocks and masses of sheared shale could slide eastward and accumulate on the Gran Cañon. Blocks of Paleozoic limestone and Gran Cañon sandstone may have been derived directly from the continent during Coloradito deposition or were deposited earlier in the Cedros "geosyncline" and later redeposited along with chert, graywacke and greenstone. Periods of megabreccia deposition alternated with deposition of sands and muds. The rarity of glaucophane schist suggests that only a relatively small amount of this rock type was being revealed at the surface during Eugenia deposition.

Termination of subduction is suggested by the contact separating Cedros and Valle formations, 4 km southwest of Cedros town where Cedros rocks are "overlain" by Valle sandstone and shale along a gently north-dipping contact. Valle strata show little structural disturbance or alteration adjacent to the contact except for being "blackened" adjacent to thin seams of serpentinite which occupy it locally. In one place, Valle strata completely surround a knoll of Cedros rocks; the orientation of the strata surrounding the knoll is essentially constant with no signs of major faulting, diapiric deformation or landsliding. This contact is interpreted as an unconformity along which serpentinite was squeezed, causing minor shearing and blackening of adjacent Valle strata. If the Cedros/Valle contact is correctly interpreted, then Cedros subduction probably terminated during the early Cretaceous (pre-Cenomanian), well in advance of the termination of Franciscan subduction in California (Page, 1970). It is not clear when Franciscan subduction along the Coast Range thrust (Barbat, 1971) began in California. Barbat (1971) proposes a late Cretaceous beginning, while Schweikert and Cowan (1975) and Dickinson (1975) suggest a late Jurassic start. If the latter age is correct, then the San Carlos fault may be an extension of the Coast Range thrust.

Other Major Structural Features

San Agustín Shear Zone.—This northwest trending structure underlies the 5 km-wide Cabo San Agustín peninsula and a limited area at Punta Prieta (Fig. 3). It consists of an extensively sheared Cedros assemblage with predominant structural trend of N50°W. The zone appears to be a southern extension of the San Benito fault

(Cohen, et al., 1963) and probably extends southeast onto the Baja California peninsula. It may represent a zone of late Cretaceous-early Tertiary strike-slip motion between oceanic and continental plates following Cedros subduction.

Border Faults.—During post-Pliocene time, three discrete Cedros blocks were uplifted along sinuous, steeply-dipping faults, herein referred to as Border faults. Fault contacts are generally marked by a band of sheared serpentinite, including gabbro and diorite blocks. The Border faults truncate all Mesozoic and Tertiary formations as well as the San Agustín shear zone and the San Carlos fault.

Summary

Structural and stratigraphic relationships on Cedros Island indicate a late Jurassic-early Cretaceous subduction interval, wherein rocks of eugeosynclinal aspect, herein named Cedros Formation, were driven beneath middle Jurassic or older ophiolite attached to the western margin of the North American plate. The San Carlos fault, which separates the ophiolite from the Cedros Formation, probably represents the subduction plane; it may represent a southern extension of the Coast Range thrust. During subduction, Cedros debris, blocks of Paleozoic limestone and middle Jurassic sandstones, were deposited as megabreccia on the ophiolite and immediately overlying beds (Gran Cañon Formation); Cedros debris may have been derived by landsliding from Cedros masses locally uplifted along the boundary of converging oceanic and continental plates. Following subduction, it is speculated that during late Cretaceous-early Tertiary time the San Agustín shear zone was developed, possibly as a result of strike-slip movement between the plates. Uplift of three major structural blocks occurred during late Pliocene time along a new set of faults, herein called Border faults, which truncated all previous formations and major structures. General uplift during latest Pliocene and Pleistocene time, accompanied by development of marine terraces, essentially brought the island mass to its present elevation.

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